Chapter 2
Project Identification

Section I
Design Management

2-1. General

Lock design is a multidisciplinary activity. Coordination among disciplines is initiated prior to hydraulic design of the filling-and-emptying system and is continued throughout the design process. Capacity and economic studies precede project authorization so that general guidance for *location*, *lockage time*, *lift variations*, *number of chambers*, *design vessel*, *usable length*, and *clear width* is available at the onset of hydraulic feature design. Capacity concerns (items B7, D5, D7, D10, E2, F2, G1, K1, K2, L1, S2, and S5) are dynamic as quality, size, and timeliness of database content and computer software and hardware capabilities change. Two WES studies (items D1 and D2) are examples of computer-based analysis of inland waterway systems. Guidance and assistance for these studies were from the Navigation Support Center (ORLPD-C), U.S. Army Engineer District, Louisville.

2-2. Design Constraints

Table 2-1 lists selected preliminary topics that influence the hydraulic design of locks. These topics, termed constraints herein, are documented prior to design. The source or cause of each constraint and, where appropriate, physical and economic values are included in the documentation. Design time is reduced when constraints are well-defined and conflicts between constraints are resolved in a timely manner. Site-specific constraints are reviewed and quantified prior to hydraulic design. Environmental issues are often site-specific due to differences in the impacts of climate, water quality, economic development, and many other factors on local ecology. Macrofouling by the nonindigenous zebra mussel (*Dreissena polymorpha*) is an example. Information regarding the effects of zebra mussel infestation is available as technical notes, workshop proceedings, and other databases. These are available from the U.S. Army Engineer Waterways Experiment Station, ATTN: CEWES-ER-A, 3909 Halls Ferry Road, Vicksburg, MS 39180-6199.

2-3. Incremental Effects

Certain factors, such as number of chambers, when incremented are a major change in project concept and are not included in feature design. Other factors, such as operation time, may be varied by the design process to increase benefits but must be economically balanced with the increase in cost. Information regarding relative unit costs of property, operational efficiencies, and structural elements can be used to develop cost-effective projects.

2-4. General Studies

The numerous multidisciplinary studies that precede hydraulic design are beyond the scope of this manual. However, the following sections summarize four study topics that commonly are used to resolve most constraints listed in Table 2-1: navigation system studies concern the interdependency of waterway, vessel, and commodity characteristics; navigation transit time studies concern the problem of expeditiously moving vessels through the project; chamber alternatives studies derive optimum chamber dimensions and number of chambers based on economic and physical factors; and geotechnical and structural studies tend to identify chamber location and type of structure.

Section II
Navigation System Characteristics

2-5. Information and Data Required

Navigation systems are addressed in the National Waterways Study (item U2) and other transportation-planning reports (item 58, for example). The studies quantify constraints imposed by standardization as well as by the system-wide transportation function. Near-project constraints concerning layout and location are described in EM 1110-2-1611 for shallow-draft waterways and in EM 1110-2-1613 for deep-draft waterways.

2-6. Waterway

The physical characteristics of a waterway such as width, depth, and bend radii limit the types of traffic that can use the channels. The type of traffic, in turn, influences the design of any lock. The Great Lakes connecting channels, the St. Lawrence Seaway, channels in estuaries, and several channels contiguous to the coast are deep enough for vessels drawing 27 to 35 feet (ft). Shallow river channels and canals limit the traffic to shallow-draft tows and pleasure craft: 14 ft, Columbia River, is the maximum design draft for U.S. tows; 9 ft, Ohio River and others, is a more common limit. Overviews of navigation systems are available (items S8 and U2). Reviews of channel development for these systems are also available (EM 1110-2-1611 and items H2 and F4). Examples of published reviews for specific systems are as follows:

Table 2-1
Examples of Constraints Considered During Hydraulic Design of Locks

Scope	Type of Constraint
Authorization	Type (New Design, Rehabilitation, Replacement)
	Funding
	Capacity Economics
	Other Authorization Requirements
System	Economics/Standardization
	Number of Parallel Chambers
	Clear Width
	Usable Length
	Lockage Procedures
	Appurtenant Equipment
	Emergency Procedures
	Vessel Characteristics
	Design Type (Shape, Length, Width, Draft)
	Vessel Mix
	Hydrology
	Projected Distribution of Flows
	Extreme (High and Low) Flows
	Ice and Debris Management
	Navigation
	Navigation Limits
	Special Needs
	Other System Requirements
Project	Multipurpose Functions
	Compatibility (Navigation)
	Compatibility (Flows)
	Lock Chamber Location
	Approach Channel Layout
	Hydrologic/Operational Projections
	Upper Pool (Maximum, Minimum, Design)
	Lower Pool (Maximum, Minimum, Design)
	Lock Status During Extreme Flows
	Lock-Structure Design Requirements
	Geotechnical (Foundations, etc.)
	Structural (Monolith Design, etc.)
	Electrical-Mechanical (Power Supply, etc.)
	Archeologic, Historic, and Environmental Requirements
	Operational Needs
	Lockage Procedures
	Emergency Closure
	Deicing (Chamber and Equipment)
	Debris and Ice Control
	Inspection and Maintenance
	Safety
	Other Operational Needs
	Construction
	Closure or Diversion
	Lock Status
	Property
	Relocations
	Acquisitions and Easements
	Other Site-Specific Concerns

Note: This listing of constraints is not exhaustive. A site-specific situation may require any item to be rigid, flexible, minor, or nonexistent. Many constraints require relative-cost studies of alternate workable schemes. The resolution of conflicts between constraints is a major part of lock design management. *Primary Function = Navigation Capacity* *a*. St. Lawrence Seaway (items B12 and D3).

b. Upper Mississippi (L&D) River (item D8).

c. New York State Barge Canal (item H7).

d. Great Lakes (item M3).

e. Lower Cumberland (item D14).

f. Columbia River (item H3).

g. Mississippi and Gulf Coast (item M11).

h. Welland Canal (item 02).

2-7. Vessels

Decisions regarding depth on the lock sills, size of chambers, guide wall layout, and to some extent the type of filling system are influenced by the types of vessels that will use the waterway. For example, recreational traffic uses locks designed for either shallow-draft (barge) or deep-draft (large ship) traffic, but there are conflicting requirements for locks that are to be used by *both* barge tows and large ships--over 75,000 deadweight tons (dwt). Maximum values of length, width, and draft are of particular concern. Larger tows are of concern in that the extent of breaking and making of tows influences decisions regarding general lock operational procedures as well as tie-up and fleeting area design. Reviews of vessel characteristics are available (items G4, S8, and U2) and are to some extent included in discussions regarding lock sizes (items B6 and D6) and vessel equipment (items D13 and H5). The contrast between barges used for the Ohio River and connecting systems (items C2 and M9) and the Columbia River system (item T1) illustrates the effect of commodity type on the commercial carrier design. Detail from these and similar reviews, because of timeliness, requires verification prior to inclusion in the design process.

2-8. Commodities

The economic studies required for lock authorization use tonnage projections that are developed through economic studies of past, present, and future commodity movements. Most engineering impacts of commodity type are resolved by studies of vessel characteristics (paragraph 2-7); certain concerns, such as the dominance of downbound versus upbound loads or the presence of hazardous or otherwise sensitive cargos, may be site-specific operational concerns.

Section III
Transit Time

2-9. Definition

The annual tonnage that can be passed through a project is influenced by

a. Time required for tows to transit the locks (transit time).

b. Number and size of lock chambers.

c. Average tonnage per tow.

d. Number of days per year that the locks can physically operate.

e. Percentage of time that tows are available for lockage.

f. Cost of delays to tows waiting lockage.

Transit time (*a* above), derived from capacity/economic studies, becomes a specific design objective; chamber option (*b* above), similarly derived, is a design constraint not usually altered by the design process; other factors (*c*-*f* above) are system characteristics. Transit time is defined as the total time required for a tow to move into a lock from a waiting point (arrival point), be raised or lowered, and then proceed out of the lock to a position where it will not interfere with any other tow that needs to transit the lock. Transit time includes

a. Time required for a tow to move from an arrival point to the lock chamber.

b. Time to enter the lock chamber.

c. Time to close the gates.

d. Time to raise or lower the lock surface (fill or empty).

e. Time to open the gates.

f. Time for the tow to exit from the chamber.

g. Time required for the tow to reach a clearance point so that another tow moving in the opposite direction can start toward the lock.

h. Time required for break down, locking through, and reassembling a tow that is too large for the lock chamber.

The objective in the overall planning of a lock project (capacity/economic studies) is to establish a value for transit time commensurate with authorization constraints (paragraph 2-2).

2-10. Evaluation

Two of the eight time components listed in paragraph 2-9 (gate operating time and filling and emptying time) are entirely dependent on the design of the lock. Approach time, entry time, exit time, and departure time are dependent on pilot skill and towboat capability and on design of approach channels, guide walls, and lock chambers. For a single lockage at modern locks, operation time constitutes only about 25 to 40 percent of the total transit time. The Performance Monitoring System is a CE-maintained database established for the purpose of monitoring parameters relative to the economic analysis of navigation locks. Transit time components are available for many existing locks in this database. Guidance regarding the Performance Monitoring System is available in Headquarters' Operations, Construction and Readiness Division, Dredging and Navigation Branch.

2-11. Chamber Performance

During hydraulic design, meeting the project capacity economic constraint requires reducing the time, termed operation time, required to fill or empty the chamber to a value equal to or less than the value used for project authorization. The within-chamber navigation constraint on rapid filling is termed chamber performance; acceptable chamber performance is normally studied by means of filling-and-emptying operations in small-scale physical hydraulic models as discussed in Chapter 6. Typical observations are as follows:

a. Surface currents and turbulence. Acceptable performance requires that surface turbulence hazardous to small vessels be identified and to the extent possible eliminated.

b. Drift of free tows. The movement of unmoored vessels (from the traffic mix) must be acceptable to navigation and lock operations and not be hazardous to either vessels or structure.

c. Hawser forces. Mooring line stresses required to restrain the vessel from longitudinal and lateral movement must be acceptable to navigation and to structural design. Specific numerical limiting values have been placed on model hawser stresses. The historic development is based on breaking strength of one used 2.5-inch (in.)-diameter manila hawser: a 10,000-pound (lb) loading has been used as a safe nonbreaking value. Many years of prototype observation and model testing have shown that when a lock is designed not to exceed the hawser stresses given in (1)-(3) below as determined in a model, the prototype mooring conditions will be satisfactory for the design vessel as well as for small craft.

(1) *Barge tows.* For various sizes and numbers of barges in any location in the lock chamber, the hawser stress as extrapolated from a model does not exceed 5 tons (2,000-lb tons).

(2) *Single vessels--ships up to 50,000 tons.* Hawser stress does not exceed 10 tons.

(3) *Single vessels greater than 50,000 tons.* Hawser stress for larger vessels is allowed to exceed 10 tons, since these vessels require more mooring lines than either barge flotillas or the smaller single vessels. Model tests indicate that if a lock-filling system is designed to meet guidance (1) and (2) above, hawser stress (extrapolated from the model) will not exceed approximately 25 tons for vessels up to 170,000 dwt.

Existing chamber feature design is based on this guidance; more severe or alternate requirements may require substantially different concepts in hydraulic feature design.

2-12. Application

Time saved during lockage is economically significant at most projects and becomes more important when growth of traffic begins to cause prolonged queuing delays. Decreased operation time causes reduced total transit time unless surges and currents in the approaches adversely affect entry and exit conditions. By means of model and prototype tests (see Chapter 6) and design studies, filling-and-emptying systems have been developed that achieve operation times near 8 minutes (min). Both severe decreases and severe increases (unless accomplished by using long valve opening times) in operation time require the development of new systems. For existing systems, operation-time benefit, usually presented as a per minute value, is used to evaluate design modifications that may vary operation time between 8 and 10 min for low-lift and 8 and 12 min for high-lift projects.

Section IV
Chamber Alternatives

2-13. General

The number and size of chambers are based primarily on capacity studies with system standardization and economics as major constraints (items B6, D6, and U2). Chamber alternatives are briefly discussed in the following paragraphs; guidance and data relating to navigation facility for both single-chamber and multichamber projects are included in EM 1110-2-1611.

2-14. Number of Parallel Chambers

In the initial development stage of a waterway transportation system, common practice has been to provide one chamber at each project; then, as traffic has increased, additional chambers have been added. For a new project on a developed waterway, where traffic patterns are well-established and continued growth is assured, two or more chambers may be initially justified on an economic basis. A need for continuous operation may lead to double chambers since, in the event of outage of one lock, essential traffic can be handled on a priority basis. In redevelopment of the Ohio River system, a minimum of two locks have been provided at each of 19 locations.

2-15. Chamber Dimensions

Chamber dimensions are influenced by sizes of existing barges and towing equipment; conversely, existing barges and towing equipment have been influenced by sizes of existing chambers. Most of the locks built in the United States since 1950 have usable horizontal dimensions of 84 by 600 ft, 110 by 600 ft, and 110 by 1,200 ft. A number of locks with other sizes have been built: 56 by 400 ft; 75-ft width with lengths varying from 400 to 1,275 ft; 80 by 800 ft; 82 by 450 ft; and 84-ft width with lengths of 400, 720, 800, and 1,200 ft. Recent western locks (along the Columbia and Snake Rivers) have usable dimensions of 86 by 675 ft. Additional lock chamber length is provided for clearance between the tow and the gates so that gate-to-gate chamber length is greater than usable length. Smaller chambers are used on waterways where the traffic is exclusively recreational boats and small craft.

2-16. Chamber Types

The majority of CE lock chambers are for commercial tows with drafts equal to or less than 14 ft, 9 ft being the most common. The design guidance in this manual is derived from studies relating to these chambers. Certain waterways require chambers that are unusual but that provide supplemental operational experience to recent CE lock design, testing, and operational data; these chambers are not evaluated herein. The following listing includes five such chambers.

a. Ship locks. Chambers used by oceangoing ships are included in the listing given in Appendix B. Lower sill submergence values for these locks are given in Table 2-2.

b. Great Lakes shipping. Commercial vessels are normally individually powered and relatively (for ships) shallow draft. For example, ships with drafts in the range of 16 to 25 ft and sizes from 15,000 to 30,000 dwt are accommodated on the Great Lakes. Lock entry and exit requirements for these types of vessels differ from either barge tow or oceangoing-ship needs (item D3).

c. Deep drafts. Chambers designed for both large tows and deep-draft ships (draft 25 ft or greater) need special entry and exit features. Sills are located sufficiently deep to accommodate squat, trim, and sinkage. Towing winches and other assisting mechanisms are used. Ships greater than 100,000 dwt are assisted into the lock chamber. A side-port design has been studied

Table 2-2
Lower Sill Submergence Values

Navigation System	Lock Name	Normal Lower Sill Submergence, ft
Gulf Intracoastal Waterway	Inner Harbor	31
Lake Washington Ship Canal	Chittendon (Large)	29
	Chittendon (Small)	16
St. Marys River, South Canal	MacArthur	31
	Poe	32
St. Marys River, North Canal	Davis	23.1
	Sabin	23.1

(item 77) for the New Ship Lock, Mississippi River-Gulf Outlet. These test results are for a 150- by 1,200-ft lock; maximum normal head = 18.4 ft; vessel draft = 45 ft (ships) and 9 and 12 ft (tows). Deep-draft navigation projects are discussed in EM 1110-2-1613.

d. Recreational locks. Locks having usable lengths less than 400 ft are listed in Appendix B and are considered recreational locks herein. Limited small-tow and special commercial vessels also use many of these locks. Small locks (and recreational vessels) are discussed in the National Waterway Study (item U2) and published literature (item G4, for example).

e. Repair facilities. Dry docks (items A5, B8, and K4, for example) and other similar chambers have mechanical and structural elements comparable to lock chambers. Expeditious closure and sealing during unwatering are major design requirements.

Section V
Foundation and Structure Concerns

2-17. Hydraulic Loading

The foundation and structural features establish the stability and durability of the structure. Hydraulic loadings during construction, completion, and operation are a major concern. These loadings, because of magnitude and spatial and temporal variations, are complex and require particularly thorough study and interdisciplinary coordination. For example, static conditions at chamber full as compared to chamber empty are recurring changes in loadings that influence deflections and stability parameters for the foundation, walls, and sills of the chamber. Known extreme conditions, such as exist during inspections, in addition to filling or emptying, cause recurring changes in differential-pressure loading across structural elements. Unusual extreme conditions, such as exist during unusual valve and emergency operation, are also of concern. For high-lift locks, the hydraulic design includes high-velocity flow so that passageways may require, for example, special treatment to avoid surface cavitation and abrasion damage. The need for relief of pore pressure within the foundation or within monolith cracks and joints is dependent on hydraulic conditions. These loadings are discussed in EM 1110-2-2602 and other structural presentations (item U1, volume II, for example).

2-18. Chamber Structure

Concrete lock structures have been generally reliable and desirable based on engineering and economic considerations. On waterways where traffic is not heavy and at locations on waterways where the lift is very low, sheet-pile locks or possibly earth wall locks have sometimes been used.

a. Concrete lock structures. The most common lock structure uses concrete gravity walls founded on either piling or rock (EM 1110-2-2002 and EM 1110-2-2602). Culverts, valve shafts, access passageways, and numerous other special-purpose cavities are contained within the wall. Intakes and outlets may also be formed in the wall although at many locks these are located well outside the actual lock chamber. More unusual concrete lock structures are of the buttress-wall type or have rock walls with anchored concrete facing. For these thin-wall designs, the filling-and-emptying system components are essentially separated from the walls. For the two parallel chambers shown in Figure 2-1, a gravity-wall low-lift design, the intermediate wall serves both chambers. A high-lift lock with concrete gravity walls is shown in Figure 2-2. In Figures 2-3 and 2-4 are high-lift designs with thinner concrete walls anchored to natural rock.

b. Sheet-pile structures. Very-low-lift projects permit structures other than concrete to be considered for design; masonry, earth embankment, and sheet-pile structures have been used. Sheet-pile lock walls are of two basic types: sheet-pile cells and M-Z sheet piling supported laterally by wales and tie rods. Sheet-pile locks are filled and emptied by sector gates or other very-low-lift systems. Gate bay monoliths are normally concrete. The low initial cost for sheet-pile structures is offset by short useful life and high maintenance. Recent use has been at sites where temporary (or emergency) locks were needed. A sheet-pile cellular lock is shown in Figure 2-5. Sheet-pile structures are commonly used for cofferdam functions and are discussed in ER 1110-2-8152 and in published literature (items C7 and S10).

c. Earth embankments. Earth embankments with concrete gate bays are considered for low-use, very-low-lift projects. For example, these locks are included in the Gulf Intracoastal Waterway to prevent saltwater intrusion and to prevent adverse or dangerous currents during abnormal tide conditions. The walls are essentially

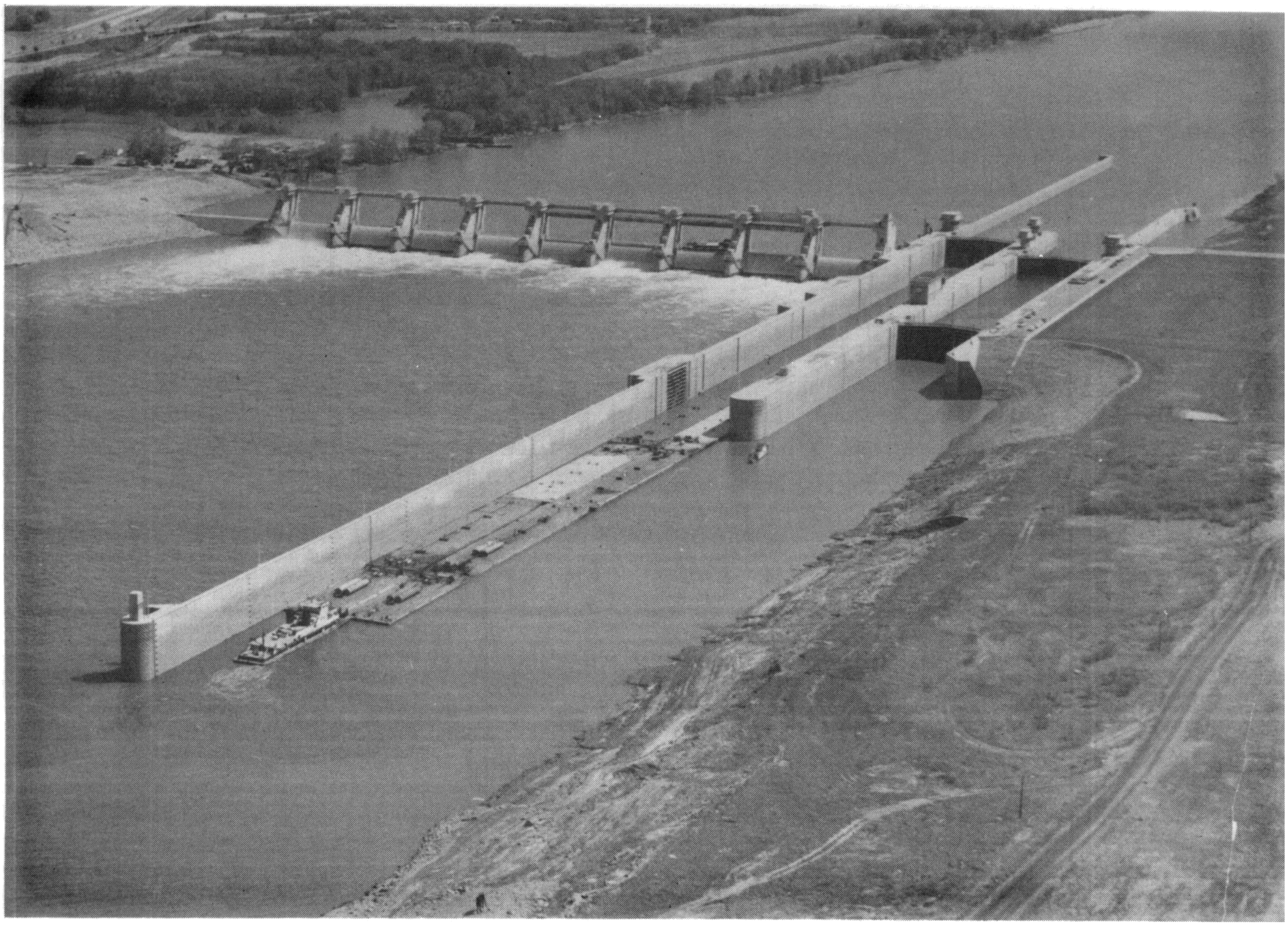

Figure 2-1. Parallel locks with gravity walls. Willow Island Locks, Ohio River, with design lift = 20 ft

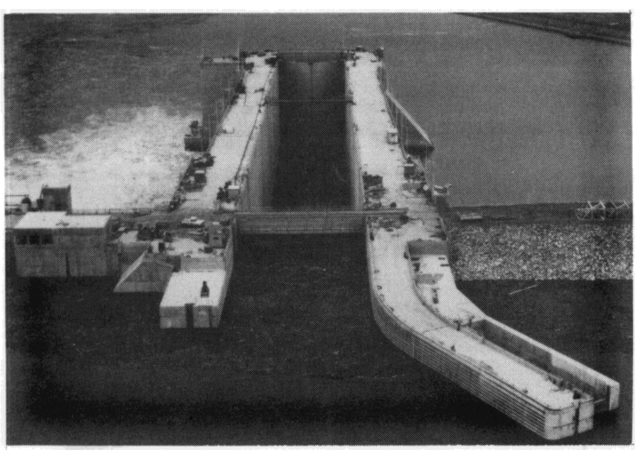

Figure 2-2. Lock with gravity walls. Lower Granite Locks, Snake River, with design lift = 100 ft

levees, with riprap protection on the side slopes. Riprap protects the bottom of the channel (the chamber) from scour due to towboat propellers. Tows moor to timber guide walls during lockage. A lock of this type equipped with sector gates is shown in Figure 2-6. Geotechnical guidance concerning embankment (levees, for example) design is applicable.

2-19. Guide and Guard Walls

Navigation needs (see EM 1110-2-1611 and EM 1110-2-1613) require the proper location and alignment of guide and guard walls and are resolved by means of general river hydraulic models; project purposes in addition to navigation are normally also of concern. These studies, which require preliminary estimates of lockage inflow

Figure 2-3. Lock with thin walls. The Dalles Lock, Columbia River, with design lift = 88 ft (under construction)

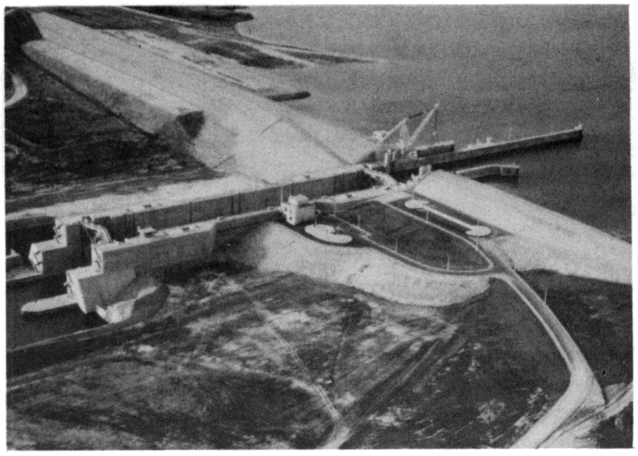

Figure 2-4. Lock with thin walls. Bay Springs Lock, Tennessee-Tombigbee Waterway, with maximum design lift = 92 ft

and outflow hydrographs, also determine the impact on navigation regarding type of wall (i.e., floating, ported, or solid). When navigation needs are resolved, then construction and maintenance economics determine the type of wall actually used at a specific project. Similarly, the heights of guide, guard, and lock walls are influenced by operational as well as navigational needs during high river stages. The following are examples of structural types:

a. Concrete gravity walls.

b. Concrete walls supported by structural cellular piling.

c. Timber walls supported by pile clusters.

d. Floating moored caisson structures.

Timber structures are normally limited to very-low-lift locks preferably where traffic consists of smaller tows.

2-20. Other Structures

Navigation conditions may require mooring facilities, fleeting areas, and other aides. Examples of structures currently in use are pile dikes (Columbia River, item D11), pile cluster dolphins (item E5), and caissons such as those used for barge docks (item H4). Energy absorption required due to barge impact is a design concern as noted in the reference items; fendering (item R6, for example) structural design guidance is included in EM 1110-2-2703.

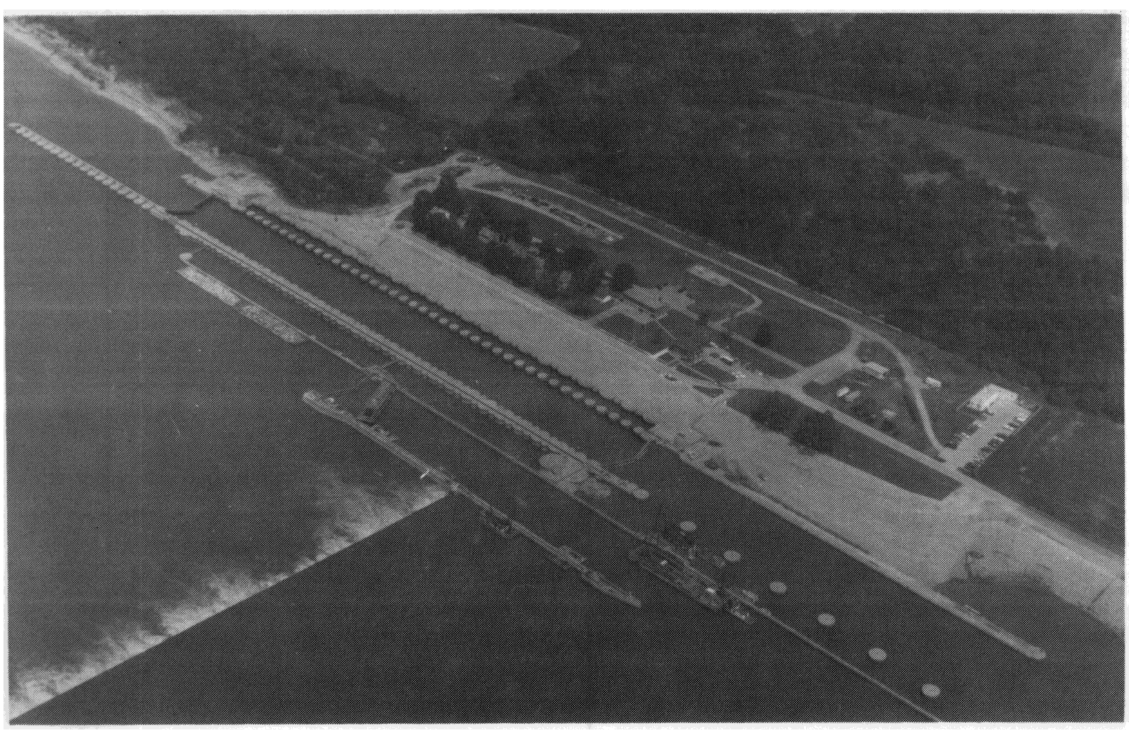

Figure 2-5. Temporary lock with cellular sheet pile. Lock and Dam No. 52, Ohio River, with design lift = 12 ft

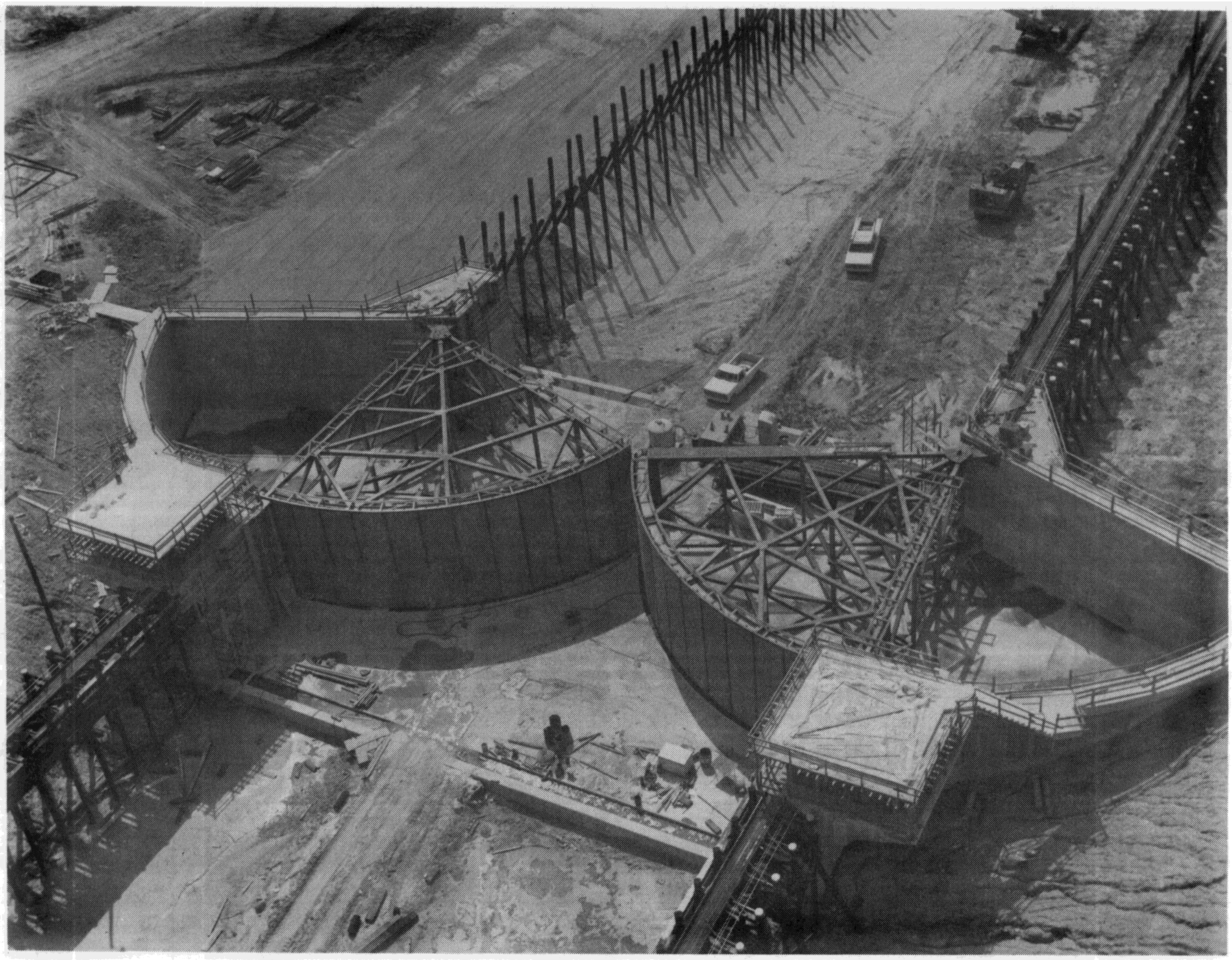

Figure 2-6. Earth embankment with concrete gate bays and sector gates. Vermilion Lock, Gulf Intracoastal Waterway, with design lift = 3 ft (under construction, 1984)